

TAN TSF-07 Pond Radium-226 Concentrations and Corrections

J. R. Giles

Project File Number TSF-07-98

Project/Task WAG-1 Sampling

Subtask TSF-07 Radium-226 Sampling

Title: TAN TSF-07 Pond Radium-226 Concentrations and Corrections

Summary: Radium-226 was identified as a risk driver in the TSF-07 disposal pond at Test Area North (TAN). It was proposed that additional sampling of the pond area be conducted to further evaluate the Ra-226 concentrations in the pond. A more detailed investigation of the existing TSF-07 Ra-226 data, and the background Ra-226 concentrations showed that the Ra-226 data obtained by gamma spectrometric analysis was biased high due to interference in the gamma-ray spectra from uranium-235 (U-235). Two methods were developed to accurately estimate the actual Ra-226 concentrations from the existing data. The first method removes the U-235 contribution and allows calculation of the actual Ra-226 concentration based on documented and accepted nuclear decay information. The second method assumes secular equilibrium of the U-238 decay chain and uses the bismuth-214 (Bi-214) and lead-214 (Pb-214) data to infer the Ra-226 concentrations. The two methods produce comparable results, showing that the Ra-226 is at background levels. Additional statistical evaluation of the existing data sets show with 95% confidence that the TSF-07 Ra-226, Bi-214, and Pb-214 data could have come from the same population of data as the background data sets.

This EDF provides the basis and justification to eliminate the need to perform any further sampling of the TSF-07 pond for Ra-226.

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| John R. Giles | 4160 | R. P. Wells <i>J.R. Giles</i> | 6/1/98 | D. J. Kuhns <i>D.J. Kuhns</i> | 6-1-98 |
| <i>John R. Giles</i> | | LMITCO Review | Date | LMITCO Approval | Date |

ABSTRACT

Radium-226 was identified as a risk driver in the TSF-07 disposal pond at Test Area North (TAN). It was proposed that additional sampling of the pond area be conducted to further evaluate the Ra-226 concentrations in the pond. A more detailed investigation of the existing TSF-07 Ra-226 data, and the background Ra-226 concentrations showed that the Ra-226 data obtained by gamma spectrometric analysis was biased high due to interference in the gamma-ray spectra from uranium-235 (U-235). Two methods were developed to accurately estimate the actual Ra-226 concentrations from the existing data. The first method removes the U-235 contribution and allows calculation of the actual Ra-226 concentration based on documented and accepted nuclear decay information. The second method assumes secular equilibrium of the U-238 decay chain and uses the bismuth-214 (Bi-214) and lead-214 (Pb-214) data to infer the Ra-226 concentrations. The two methods produce comparable results, showing that the Ra-226 is at background levels. Additional statistical evaluation of the existing data sets show with 95% confidence that the TSF-07 Ra-226, Bi-214, and Pb-214 data could have come from the same population of data as the background data sets. This EDF provides the basis and justification to eliminate the need to perform any further sampling of the TSF-07 pond for Ra-226.

TSF-07 Ra-226 CONCENTRATIONS AND CORRECTIONS

INTRODUCTION

Historical data from a 1989 characterization of the TSF-07 pond show that radium-226 (Ra-226) concentrations obtained by gamma spectrometric analysis are unacceptably high, according to the *Comprehensive Remedial Investigation/Feasibility Study for the Test Area North Operable Unit 1-10 at the Idaho National Engineering and Environmental Laboratory* (Blackmore et al. 1998). Additionally, there is a background Ra-226 data set that reports high concentrations for Ra-226 from various sample points across the INEEL (Burns 1997).

There are three radionuclide concentration data sets that will be referred to in this document:

1. The 1989 historical data set from the TSF-07 pond. This data set includes Ra-226, bismuth-214 (Bi-214), and lead-214 (Pb-214) concentrations, as determined by gamma-ray spectroscopy, for the TSF-07 pond area (Medina 1993).
2. A background laboratory Quality Control (QC) study performed by L. Don Koeppen. This data set consists of two background data sets, for analytical QC purposes, from different facilities across the INEEL, and is summarized in Appendix A. A summary of the Ra-226 data is presented in Doug Burns' letter dated December 17, 1997 (Burns 1997), and a summary of the Bi-214 and Pb-214 data is presented in Rosanna Chambers' letter dated April 13, 1998 (Chambers 1998).
3. The data set contained in a summary report by S. M. Rood et al. Rood's document reports background uranium-238 (U-238) concentrations for the INEEL (Rood et al. 1994). The importance of U-238 concentrations will be presented later in this paper.

It has been determined through personal conversations with L. Don Koeppen (Radiochemist, INEEL Sample Management Office), that the reported concentrations for Ra-226 in both the TSF-07 data set and the background QC data set are systematically biased high. This bias is caused by interference from gamma-rays emitted by uranium-235 (U-235). It is important to note here that Ra-226 and U-235 are found in nature, and based on process knowledge and historical records, there is no reason to suspect that discharges to the pond increased the levels of either Ra-226 or U-235 above background. These data sets provide a strong basis for concluding that Ra-226 concentrations in the TSF-07 pond are at background levels.

PROPOSED METHODS FOR REVIEWING RA-226 DATA

Although the Ra-226 data obtained by gamma spectroscopy is typically biased high, it can be corrected and defended. Two methods are proposed for reviewing the Ra-226 data: (1) the Ra-226 data can be corrected to remove the bias, and (2) The Bi-214 and Pb-214 data from the TSF-07 and background data sets can be used to infer the actual Ra-226 concentrations.

Corrected Ra-226 Concentrations

Correction of the Ra-226 data can be accomplished by calculating the individual Ra-226 and U-235 contributions to the composite gamma-ray peak in the gamma-ray spectrum. This calculation is made based on the following:

- The isotopic ratios of U-235 and U-238 are at the naturally occurring levels of 0.72% and 99.28%, respectively (Browne & Firestone 1986).
- The U-238 decay chain is in secular equilibrium (Eisenbud 1987). The activity of the daughter, Ra-226, is equivalent to that of the parent, U-238.
- The difference in counting efficiencies for the Ra-226 gamma-ray and the U-235 gamma-ray is negligible (Giles 1998).

Based on the above statements of fact, the correction factor for the Ra-226 data sets, obtained by gamma-ray spectroscopy, is 0.571 (see Appendix B for derivation). This factor removes the U-235 contribution to the observed gamma-ray signal, and reduces the inaccurate and high Ra-226 concentrations by approximately 43%. Applying the correction factor to the TSF-07 data set reduces the average Ra-226 concentration from 2.16-pCi/g to 1.23-pCi/g, and the maximum concentration of 4.54-pCi/g is reduced to 2.59-pCi/g. (See Table 1.)

Ra-226 Concentrations from Bi-214 and Pb-214

The second approach that may be taken for using the existing data is to use the Bi-214 or Pb-214 concentrations from the TSF-07 pond and background data sets. The Bi-214 and Pb-214 are radionuclides in the U-238 decay chain. (Bismuth-214 and Pb-214 are daughter products produced after the decay of Ra-226.) The Bi-214 and Pb-214 data could be used to infer Ra-226 concentrations based on the following assumption:

- The U-238 decay chain in the soil samples was in secular equilibrium at the time the sample was counted (Koeppen 1998a).

It is generally accepted that the U-238 chain is in secular equilibrium in the INEEL soils (Rood et al. 1996); however, a concern with the historical sample data is that the equilibrium was disturbed during the sampling by emanation of radon-222 (Rn-222) gas, and the samples were not allowed to establish equilibrium prior to making the laboratory measurements. According to McHugh, when soil samples are collected the equilibrium is not significantly disturbed. Soil samples that are placed directly into the sample container and sealed in the field are very near equilibrium (McHugh 1995), and by the time the samples are shipped and processed through the laboratory, secular equilibrium conditions exist. It has been shown that more aggressive sample preparation methods, such as grinding or milling the soil, do disrupt the equilibrium (McHugh 1995). According to conversations with L. Don Koeppen, the soil samples from the TSF-07 area and the background study in question were not ground or milled, the samples were placed in containers with lids in the field and sent to the RML for analysis. Although the Doug Burns letter (Burns 1997) states "the samples were taken from the ground and analyzed without sealing them...," the samples were actually placed in containers with lids (Koeppen 1998b). Analysis of the samples took place a minimum of two weeks after receipt at the RML (Koeppen 1998a). The Bi-214 and Pb-214 data sets from TSF-07 and the background QC study are summarized in the attached letter and in Table 2 (Chambers 1998).

Table 1. Method 1: Corrected Ra-226 concentrations.

| | Reported Ra-226 Concentrations (pCi/g) | | | Corrected Ra-226 Concentrations (pCi/g) | | |
|-----------------------|--|---------|--------|---|---------|--------|
| | Bkg. #1 | Bkg. #2 | TSF-07 | Bkg. #1 | Bkg. #2 | TSF-07 |
| Average Concentration | 2.14 | 2.12 | 2.16 | 1.22 | 1.21 | 1.23 |
| Minimum Concentration | 0.67 | 0.79 | 1.21 | 0.38 | 0.45 | 0.69 |
| Maximum Concentration | 4.54 | 3.85 | 4.54 | 2.59 | 2.20 | 2.59 |

Table 2. Method 2: Ra-226 concentrations inferred from Bi-214 and Pb-214 data.

| | Reported Ra-226 Concentrations (pCi/g) | | | Corrected Ra-226 Concentrations (pCi/g) | |
|-----------------------|--|---------|--------|---|--------|
| | Bkg. #1 | Bkg. #2 | TSF-07 | Bkg. (Average) | TSF-07 |
| Average Concentration | 2.14 | 2.12 | 2.16 | 1.1 | 0.98 |
| Minimum Concentration | 0.67 | 0.79 | 1.21 | 0.57 | 0.59 |
| Maximum Concentration | 4.54 | 3.85 | 4.54 | 1.52 | 1.61 |

Data Summary

The two methods described above have been applied to the data sets from TSF-07 and background, thereby removing the bias from the reported average minimum and maximum Ra-226 concentrations. The following tables summarize the historical data and the results of using the above methods to correct the Ra-226 data.

Average Ra-226 concentrations are presented in Table 2. These average concentrations are the average of the reported Bi-214 and Pb-214 concentrations. The methodologies presented here provide similar results for corrected Ra-226 concentrations; although, the values reported from Method 2 are slightly lower.

There is limited documentation on the background concentrations of radium and other naturally occurring radioactive materials at the INEEL; however, Rood et al. presented a summary of radionuclide concentrations for the INEEL. This summary reports a Site-wide U-238 background concentration upper tolerance limit (UTL) of 1.85-pCi/g and 2.15-pCi/g at the 95% and 99% confidence intervals, respectively. Briefly stated the UTL is the concentration that implies a certain level of confidence (i.e. 95% or 99%) that at least 95% of the data within a given data set will be below the UTL. The corrected average Ra-226 concentrations in Tables 1 and 2 above are less than the UTLs for U-238 and its progeny (Rood et al. 1996).

The validity and usability of the historical data sets is questionable. The following describes the limitations and validation of the data sets.

- The 1989 data set from TSF-07, referenced in Medina, 1993, is archived, and can be retrieved, if necessary for data validation.
- The gamma-ray spectra for the background QC data set from L. D. Koeppen has been discarded and is not retrievable.
- The only record of the background QC data set from L. D. Koeppen are the data sheets attached to the interoffice correspondence (Burns 1997). There is no logbook record of the sample collection date and area sampled. (The sample locations are identified by a date and general location on the data sheets.)
- It is assumed, but cannot be validated on paper, that the samples from TSF-07 and the background QC study were collected and analyzed in a similar manner (Burns 1997). This is supported by personal conversation with L. Don Koeppen, who stated that both data sets were analyzed by gamma-ray spectroscopy at the Test Reactor Area (TRA) Radiological Measurements Laboratory (RML), and that the sample collection and preparation methods were similar (Koeppen 1998a).
- The quality of the analytical data can be supported by the analytical instruments used by the RML to perform the analyses of the TSF-07 and background QC study data. The analytical instruments and procedures for analysis contained several QA/QC steps. These included routine instrument response checks, energy and efficiency calibration checks, background checks, use of a dual energy pulser system to ensure and verify precision and accuracy of each sample measurement, and an internal laboratory (RML) review and validation of each sample result (Koeppen 1998a).
- The quality of the data sets referred to in Rood et al., are addressed therein.

The data sets referred to in this EDF have different levels of quality associated with them. The level of quality associated with the TSF-07 data is high, and is of the most importance because this data can be used to show the Ra-226 concentrations are at background. The other two data sets serve as a reference for background concentrations of naturally occurring radionuclides, and the background QC data set also serves as a direct comparison with the TSF-07 data because sample collection, preparation, and analytical methods were almost identical (Koeppen 1998a).

CONCLUSION

This document, in conjunction with the LMITCO internal correspondence letters, provides a strong, valid argument that the Ra-226 levels in the TSF-07 pond are at background levels. This paper acknowledges that the historical TSF-07 data and the L. Don Koeppen background QC data obtained by direct gamma spectrometric measurements is biased high due to the U-235 interference; however, the bias can be removed from the two data sets using one of the two methods presented in this paper. The letters from D. Burns and R. Chambers conclude, with 95% confidence, that the Ra-226 concentrations in the TSF-07 pond are at background.

REFERENCES

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- Browne, E. and R. B. Firestone, 1986, *Table of Radioactive Isotopes*, John Wiley & Sons, New York, 1986.
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- Eisenbud, M., 1987, *Environmental Radioactivity From Natural, Industrial, and Military Sources*, Harcourt Brace Jovanovich, San Diego, 1987.
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- McHugh, J. A., *Isotopic Analysis of Uranium in Contaminated Soils by Gamma-Ray Spectroscopy*, Hilbert Associates, Inc., Saratoga Springs, NY.
- Medina, S. M., July 1993, *Evaluation of Historical and Analytical Data on the TAN TSF-07 Disposal Pond*, EGG-ERD-10422, July 1993.
- Rood, S. M., et al., 1996, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory*, INEL-94/0250, August 1996.

APPENDIX A

L. Don Koeppen QC Data Set Summary

Ra-226 Background Qualtiy Control Study Data
Summary of Sample Numbers, Locations, Dates and Analytes
(Data from L. Don Koeppen, INEEL SMO)

Background Study, Data Set #1

| Date | Location | Analyte(s) | # of Samples |
|---------------------------|----------------|----------------|--------------|
| Nov-89 | Surface | Pb-214, Ra-226 | 12 |
| Oct-89 | Surface | Pb-214, Ra-226 | 44 |
| Jul-90 | Surface | Pb-214, Ra-226 | 5 |
| Aug-90 | PSD*-surface | Pb-214, Ra-226 | 31 |
| Nov-89 | TSF | Pb-214, Ra-226 | 6 |
| Nov-89 | TSF-surface | Pb-214, Ra-226 | 36 |
| Nov-89 | TSF-subsurface | Pb-214, Ra-226 | 16 |
| Dec-89 | CFA-surface | Pb-214, Ra-226 | 21 |
| Dec-89 | CFA-subsurface | Pb-214, Ra-226 | 7 |
| Feb-90 | ARA | Pb-214, Ra-226 | 2 |
| Feb-90 | ARA-surface | Pb-214, Ra-226 | 1 |
| Feb-90 | ARA-subsurface | Pb-214, Ra-226 | 3 |
| TOTAL # OF SAMPLES | | 184 | |

Background Study, Data Set #2

| Date | Location | Analyte(s) | # of Samples |
|---------------------------|-----------------------|--------------------------|--------------|
| Nov-89 | TSF-surface | Pb-214, Ra-226 | 56 |
| Dec-89 | CFA | Pb-214, Ra-226 | 28 |
| Feb-90 | ARA | Pb-214, Ra-226 | 6 |
| Jul-90 | CPP Chem.Pond-surface | Pb-214, Ra-226 | 36 |
| Aug-90 | PSD-surface | Pb-214, Ra-226 | 30 |
| Sep-91 | NPR* | Bi-214, Pb-214, Ra-226 | 45 |
| Mar-92 | PAD A Overburden | Bi-214, Pb-214, Ra-226 | 23 |
| May-92 | RWMC-surface | Bi-214, Pb-214, Ra-226 | 23 |
| Jun-92 | RWMC-soils | Bi-214, Pb-214, Ra-226 | 8 |
| Apr-93 | TSF Sewage Plan Soils | Bi-214, Pb-214, Ra-226** | 7 |
| TOTAL # OF SAMPLES | | 262 | |

*PSD=Paint Shop Ditch at CFA.

*NPR=New Production Reactor

**There were only 6-samples from this set that were analyzed for Ra-226.

APPENDIX B

**Method for Removing the U-235 Contribution to the Ra-226
Reported Concentrations as Determined by Gamma-Ray
Spectroscopy**

METHOD FOR REMOVING THE U-235 CONTRIBUTION TO THE Ra-226 REPORTED CONCENTRATIONS AS MEASURED BY GAMMA-RAY SPECTROSCOPY

John R. Giles
LMITCO
P.O. Box 1625
Idaho Falls, Idaho 83415-3953

April 14, 1998

Direct measurement of ^{226}Ra by gamma-ray spectroscopy in environmental samples is often difficult, and consistently reports concentrations that are inaccurately high. The reason for the inaccuracy is failure to correct the data for the interference from ^{235}U . Both ^{226}Ra and ^{235}U are present in soils naturally. Uranium is the parent radionuclide in the Actinium decay series, and ^{226}Ra is one of the progeny in the ^{238}U decay chain. Although members of different decay series, both ^{226}Ra and ^{235}U decay by alpha particle emission, followed by the emission of gamma-rays. The interference in the ^{226}Ra measurement comes from the 185.739-keV gamma-ray emitted by ^{235}U . This is a problem because ^{226}Ra emits a gamma-ray at 186.11-keV (Browne & Firestone), and for the high-purity germanium (HPGe) detectors used for analysis, these gamma-rays are indistinguishable.

The following derivation is a method that can be used to resolve the individual contributions of ^{235}U and ^{226}Ra to the composite peak at approximately 186-keV in a gamma-ray spectrum.

Given

Energies and Branching Ratios of Gamma-rays (Browne & Firestone 1986):

$$E_{U^{235}} = 185.739\text{ keV} \quad N_{U^{235}} = 0.53 \frac{\gamma}{\text{dis.}}$$

$$E_{Ra^{226}} = 186.11\text{ keV} \quad N_{Ra^{226}} = 0.0328 \frac{\gamma}{\text{dis.}}$$

Isotopic Abundance's of Uranium Isotopes in soils (Browne & Firestone 1986):

$$I_{U^{235}} = 0.720\%$$

$$I_{U^{238}} = 99.2745\%$$

Specific Activities of Uranium Isotopes in natural uranium (Eisenbud 1987):

$$SA_{U^{235}} = 1.54 \times 10^4 \frac{pCi}{g} (^{nat}\text{U})$$

$$SA_{U^{238}} = 3.33 \times 10^5 \frac{pCi}{g} (^{nat}\text{U})$$

The ratio of the Specific Activities is then:

$$(1) \quad \frac{SA_{U^{235}}}{SA_{U^{238}}} = \frac{1.54 \times 10^4 (pCi/g)}{3.33 \times 10^5 (pCi/g)} = 4.667 \times 10^{-2}$$

Assumptions

- It is assumed that the ^{238}U decay chain is in secular equilibrium in the sample.

This assumption is based on the fact that the ^{238}U equilibrium is well established in the INEEL soils (Rood et al. 1996), and that the equilibrium is undisturbed during the sample preparation and preservation (McHugh). It is re-emphasized here that the samples and results from the L. Don Koeppen and the 1989 TSF-07 pond data sets were collected in sealed containers, and counted with no sample preparation.

- The counting efficiencies of any given HPGe detector system is nearly identical for the two gamma-ray energies in question (i.e. 185.739-keV, and 186.11-keV).

It can be shown that the efficiencies are identical, or nearly so, by the following:

The absolute counting efficiency, $\varepsilon(E)$, of a detector system can be defined in very general terms as:

$$(2) \quad \varepsilon(E) = k \cdot E$$

where E is the gamma-ray energy in keV, and k is an empirically determined constant.

Furthermore, for any given detector system, k is a constant for all energies such that

$$(3) \quad k = \frac{\varepsilon(E_1)}{E_1} = \frac{\varepsilon(E_2)}{E_2}$$

$$(4) \quad \frac{\varepsilon(E_1)}{\varepsilon(E_2)} = \frac{E_1}{E_2}$$

Specifically,

$$(5) \quad \frac{\varepsilon(185.739)}{\varepsilon(186.11)} = \frac{185.739}{186.11} = 0.998$$

This shows that the difference in the efficiencies is less than 0.2%, and does not significantly contribute to the remainder of the calculations presented in this paper.

Correction Factor Derivation

If we have a 1-gram sample of soil, and it has been determined that the ^{238}U concentration is 1-pCi/g, then from Equation 1 above, the ^{235}U concentration is 4.667×10^{-2} -pCi/g. Furthermore, the respective total activities in the 1-g sample are 1-pCi and 4.667×10^{-2} -pCi for ^{238}U and ^{235}U . Using the assumption that the ^{238}U decay chain is in equilibrium, then we can also assume the ^{226}Ra concentration in the sample is 1-pCi. In terms of Bequerels (disintegrations/second), these activities are:

$$A_{\text{Ra}^{226}} = 3.7 \times 10^{-2} \text{ Bq}$$

$$A_{\text{U}^{235}} = 1.727 \times 10^{-3} \text{ Bq}$$

These values can be used to calculate the gamma-ray production rates from ^{226}Ra and ^{235}U in our sample:

$$(6) \quad \gamma_{\text{Ra}} = (3.7 \times 10^{-2} \text{ dis/s}) \cdot (0.0328 \gamma/\text{dis}) = 1.21 \times 10^{-3} \gamma/\text{s}$$

$$(7) \quad \gamma_{\text{U}} = (1.727 \times 10^{-3} \text{ dis/s}) \cdot (0.53 \gamma/\text{dis}) = 9.15 \times 10^{-4} \gamma/\text{s}$$

To quantify the individual contributions of ^{226}Ra and ^{235}U to the 186-keV gamma-ray signal, we simply take the ratio of the gamma-ray production rates:

$$(8) \quad \frac{\gamma_{\text{Ra}^{226}}}{\gamma_{\text{U}^{235}}} = \frac{1.21 \times 10^{-3} \gamma/\text{s}}{9.15 \times 10^{-4} \gamma/\text{s}} = 1.33$$

In fractional form, this can be written as:

$$(9) \quad \frac{\gamma_{\text{Ra}^{226}}}{\gamma_{\text{U}^{235}}} = \frac{4 \gamma/\text{s}}{3 \gamma/\text{s}}$$

This means that for every seven gamma-rays that are counted by the detector system (at 186-keV), four gamma-rays are from ^{226}Ra , and three gamma-rays are from ^{235}U . In terms of a decimal equivalency, 57.1% of the gamma-rays are from ^{226}Ra , and 42.9% gamma-rays are from ^{235}U .

The relationship developed in Equation 9 can be used to determine the actual ^{226}Ra concentration from the reported concentration. Simply multiplying the reported concentration by 0.571 will yield the correct ^{226}Ra concentration; likewise, multiplying the reported concentration by 0.429 will yield the correct ^{235}U concentration.

ATTACHMENT 1

LIMITCO Interoffice Correspondence

NOTE: The attached data sets were recreated from the originals. The original data was scanned electronically and cleaned-up. The scanned data tables were verified against the originals for accuracy.

Lockheed Martin Idaho Technologies Company**INTERDEPARTMENTAL COMMUNICATION**

Date: December 18, 1997

To: Tim Green MS 4160 6-9420

From: Doug Burns  MS 3960 6-4324

Subject: RA-226 BACKGROUND CONCENTRATION DATA - DEB-23-97

- References:**
- (a) Medina, S.M., 1993, Evaluation of Historical and Analytical Data on the TAN TSF-07 Disposal Pond, EGG-ERD-10422, July 1993.
 - (b) Gilbert, R.O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, NY, NY

Attached to this letter are the results of two unpublished Ra-226 background concentration studies. Don Koeppen of Lockheed Martin Idaho Technologies Company performed both studies as part of a laboratory quality assurance program. The results of the studies indicate that the Ra-226 concentrations detected in the TSF-07 disposal pond, and presented in reference a, are very similar to Idaho National Engineering and Environmental Laboratory (INEEL) background concentrations. The following paragraphs provide more detail about the background studies and the TSF-07 sampling results.

The background studies were performed on soil samples that were collected from locations around the INEEL starting in the spring of 1989. The samples were collected from both surface (i.e., depths less than or equal to 5 cm) and subsurface locations and they did not contain any man-made contamination.

All of the samples were analyzed in an unprepared state using gamma spectrometry. In other words, the samples were taken from the ground and analyzed without sealing them to prevent the gaseous escape of Rn-222 or waiting for buildup of Pb-214 and Bi-214 daughter products. This analytical method was similar to the method that was used to collect the TSF-07 sample results presented in Reference a.

The first background study evaluated 221 samples and the second study evaluated 261 samples. Four of the samples in the first study were identified as outliers, and 33 other samples were collected from pond sediments at CPP. These 37 samples were not considered to be similar to the other 184 samples in the first study, so they were removed from the data set.

The following table shows the average concentrations, standard deviation, variance, minimum, and maximum of the two background studies and the TSF-07 pond results.

Tim Green
December 18, 1997
DEB-23-97
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Table 1. Comparison of Ra-226 concentrations from two background sampling studies with concentrations detected at the TSF-07 disposal pond.

| | Background Study #1 | Background Study #2 | TSF-07 Pond Sampling |
|-------------------------------|------------------------|------------------------|-------------------------|
| Number of Samples | 184 | 261 | 80 |
| Average Concentration (pCi/g) | 2.14 | 2.12 | 2.16 |
| Standard Deviation | 0.60 | 0.64 | 0.60 |
| Variance | 0.36 | 0.41 | 0.35 |
| Minimum Concentration (pCi/g) | 0.67 | 0.79 | 1.21 |
| Maximum Concentration (pCi/g) | 4.54 | 3.85 | 4.54 |

The TSF-07 pond data was compared to the background study #2 data using a Wilcoxon Rank Sum Test. This test was performed using the procedure presented on page 248 of reference b, and was used to determine if the two data sets could have been drawn from one Ra-226 background population. The results of the test indicate that there is a 95% probability that the TSF-07 data belongs to the same population as the background study #2 data. This is a strong indication that the Ra-226 concentrations that were detected in the TSF-07 pond are background concentrations.

bma

cc: Don Koeppen, MS 3960
 Dave Michael, MS 3953
 Walt Sullivan, MS 3960
 File Code 6102
 ARDC Files, MS 3922
 Doug Burns Letter File

Background QC Data Set #1

BACKGROUND STUDY, DATA SET #1

ENVIRONMENTAL SOIL SAMPLES

| DATE EVALUATED | SAMPLE LOCATION | DETECTOR | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-------------------|--------------------|----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| 11/14/89 | SURFACE | A3 | 18.70 | 1.29 | 1.51 | 2.29 | 1.30 | 21.50 |
| 11/14/89 | SAMPLES | A3 | 18.50 | 1.40 | 1.49 | 2.56 | 1.44 | 21.39 |
| 11/14/89 | (less than 5-cm) | A3 | 14.46 | 1.16 | 1.24 | 1.82 | 1.12 | 16.85 |
| 11/14/89 | | A3 | 19.65 | 1.38 | 1.40 | 1.55 | 1.31 | 22.42 |
| 11/14/89 | [EMPSMPLS.WK] | A3 | 16.21 | 1.33 | 1.32 | 2.46 | 1.21 | 18.86 |
| 11/14/89 | | A3 | 17.00 | 1.26 | 1.63 | 2.19 | 1.18 | 19.89 |
| 11/14/89 | | A3 | 15.06 | 1.27 | 1.41 | 3.31 | 1.25 | 17.74 |
| 11/14/89 | | A3 | 18.81 | 1.33 | 1.65 | 2.26 | 1.33 | 21.79 |
| 11/14/89 | | A3 | 19.01 | 1.34 | 1.34 | 2.76 | 1.47 | 21.69 |
| 11/14/89 | | A3 | 17.49 | 1.28 | 1.32 | 1.90 | 1.37 | 20.09 |
| 11/14/89 | | A3 | 20.75 | 1.56 | 1.63 | 2.45 | 1.50 | 23.94 |
| 11/14/89 | | A3 | 18.89 | 1.48 | 1.33 | 2.86 | 1.47 | 21.70 |
| 10/24/89 | | A4 | 17.55 | 1.30 | 1.21 | 1.33 | 1.19 | 20.06 |
| 10/24/89 | | A4 | 19.54 | 1.14 | 1.60 | 1.89 | 1.35 | 22.27 |
| 10/24/89 | | A4 | 13.73 | 1.30 | 1.11 | 1.05 | 1.14 | 16.14 |
| 10/24/89 | | A4 | 18.14 | 1.29 | 1.24 | 1.65 | 1.47 | 20.68 |
| 10/24/89 | | A4 | 15.37 | 1.25 | 1.28 | 2.21 | 1.06 | 17.89 |
| 10/24/89 | | A4 | 17.99 | 1.12 | 1.26 | 1.55 | 1.14 | 20.37 |
| 10/24/89 | | A4 | 16.73 | 1.17 | 1.06 | 1.38 | 1.15 | 18.96 |
| 10/24/89 | | A4 | 14.24 | 1.21 | 1.06 | 1.81 | 1.25 | 16.51 |
| 10/24/89 | | A4 | 14.14 | 1.10 | 1.16 | 1.89 | 1.37 | 16.39 |
| 10/24/89 | | A4 | 21.06 | 1.52 | 1.46 | 2.49 | 1.40 | 24.03 |
| 10/24/89 | | A5 | 16.78 | 1.25 | 1.31 | 2.34 | 1.30 | 19.33 |
| 10/24/89 | | A5 | 17.54 | 1.18 | 1.38 | 2.18 | 1.38 | 20.10 |
| 10/24/89 | | A5 | 16.34 | 1.28 | 1.16 | 2.19 | 1.09 | 18.78 |
| 10/24/89 | | A5 | 18.56 | 1.32 | 1.09 | 1.26 | 1.42 | 20.97 |
| 10/24/89 | | A5 | 18.82 | 1.36 | 1.52 | 2.73 | 1.24 | 21.70 |
| 10/24/89 | | A5 | 19.85 | 1.44 | 1.34 | 1.69 | 1.36 | 22.63 |
| 10/24/89 | | A5 | 17.76 | 1.51 | 1.44 | 1.96 | 1.25 | 20.71 |
| 10/24/89 | | A5 | 17.69 | 1.39 | 1.20 | 2.41 | 1.39 | 20.27 |
| 10/24/89 | | A5 | 15.78 | 1.55 | 1.11 | 2.31 | 1.33 | 18.44 |
| 10/24/89 | | A5 | 15.20 | 1.42 | 1.50 | 2.01 | 1.32 | 18.12 |
| 10/24/89 | | A5 | 17.08 | 1.54 | 1.34 | 0.74 | 1.31 | 19.96 |
| 10/24/89 | | A5 | 14.76 | 1.28 | 1.20 | 3.50 | 1.33 | 17.23 |
| 10/24/89 | | A5 | 17.88 | 1.19 | 1.35 | 2.12 | 1.15 | 20.42 |
| 10/24/89 | | A5 | 13.87 | 1.34 | 1.11 | 1.53 | 1.32 | 16.32 |
| 10/24/89 | | A5 | 18.28 | 1.38 | 1.43 | 1.21 | 1.33 | 21.10 |
| 10/24/89 | | A5 | 18.45 | 1.53 | 1.46 | 2.30 | 1.27 | 21.43 |
| 10/24/89 | | A5 | 18.73 | 1.65 | 1.24 | 2.21 | 1.46 | 21.62 |
| 10/24/89 | | A6 | 17.88 | 1.41 | 1.55 | 1.04 | 1.40 | 20.84 |
| 10/24/89 | | A6 | 19.73 | 1.34 | 1.47 | 2.14 | 1.35 | 22.54 |
| 10/24/89 | | A6 | 18.97 | 1.43 | 1.18 | 2.19 | 1.39 | 21.58 |
| 10/24/89 | | A6 | 18.11 | 1.30 | 1.26 | 1.92 | 1.38 | 20.67 |

Background QC Data Set #1

| DATE EVALUATED | SAMPLE LOCATION | DETECTOR | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-------------------|--------------------|----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| 10/24/89 | | A6 | 18.19 | 1.51 | 1.39 | 2.56 | 1.33 | 21.09 |
| 10/24/89 | | A6 | 20.12 | 1.56 | 1.37 | 3.01 | 1.51 | 23.04 |
| 10/24/89 | | A6 | 19.08 | 1.32 | 1.14 | 1.89 | 1.29 | 21.54 |
| 10/24/89 | | A6 | 20.13 | 1.39 | 1.14 | 1.39 | 1.47 | 22.66 |
| 10/24/89 | | A6 | 17.08 | 1.41 | 1.30 | 2.69 | 1.28 | 19.79 |
| 10/24/89 | | A6 | 18.63 | 1.37 | 1.44 | 2.22 | 1.42 | 21.43 |
| 10/24/89 | | A6 | 14.53 | 1.31 | 1.27 | 1.76 | 1.23 | 17.11 |
| 10/24/89 | | A6 | 18.71 | 1.36 | 1.24 | 2.16 | 1.30 | 21.30 |
| 10/24/89 | | A6 | 15.90 | 1.14 | 1.09 | 2.39 | 1.17 | 18.14 |
| 10/24/89 | | A6 | 16.23 | 1.08 | 1.48 | 1.98 | 1.18 | 18.79 |
| 10/24/89 | | A6 | 16.29 | 1.10 | 1.16 | 2.23 | 1.30 | 18.55 |
| 10/24/89 | | A6 | 17.72 | 1.42 | 1.32 | 2.23 | 1.28 | 20.46 |
| 10/24/89 | | A6 | 19.76 | 1.56 | 1.24 | 2.37 | 1.58 | 22.57 |
| 07/30/90 | SURFACE SAMPLES | A1-A6 | 14.23 | 0.53 | 1.12 | 1.87 | 0.61 | 15.88 |
| 07/30/90 | | A1-A6 | 9.58 | 0.47 | 0.87 | 1.36 | 0.42 | 10.92 |
| 07/30/90 | | A1-A6 | 19.14 | 0.80 | 1.46 | 1.62 | 0.61 | 21.40 |
| 07/30/90 | [CHEMSUR.WK] | A1-A6 | 10.38 | 0.47 | 1.06 | 1.59 | 0.53 | 11.91 |
| 07/30/90 | | A1-A6 | 12.66 | 0.52 | 0.79 | 1.53 | 0.62 | 13.97 |
| 07/30/90 | | A1-A6 | 10.48 | 0.45 | 0.72 | 0.54 | 0.51 | 11.65 |
| 07/30/90 | | A1-A6 | 21.25 | 1.56 | 1.33 | 2.78 | 1.59 | 24.14 |
| 07/30/90 | | A1-A6 | 15.31 | 0.59 | 1.08 | 1.45 | 0.63 | 16.98 |
| 07/30/90 | | A1-A6 | 15.40 | 0.52 | 1.15 | 0.93 | 0.64 | 17.07 |
| 07/30/90 | | A1-A6 | 11.59 | 0.48 | 0.74 | 1.66 | 0.35 | 12.81 |
| 07/30/90 | | A1-A6 | 13.64 | 0.52 | 0.93 | 1.52 | 0.58 | 15.09 |
| 07/30/90 | | A1-A6 | 13.71 | 0.54 | 0.74 | 1.54 | 0.46 | 14.99 |
| 07/30/90 | | A1-A6 | 16.03 | 0.68 | 1.22 | 2.61 | 0.52 | 17.93 |
| 07/30/90 | | A1-A6 | 15.89 | 0.61 | 1.25 | 2.39 | 0.65 | 17.75 |
| 07/30/90 | | A1-A6 | 12.91 | 0.63 | 0.95 | 0.48 | 0.49 | 14.49 |
| 07/30/90 | | A1-A6 | 18.03 | 0.53 | 1.04 | 1.71 | 0.59 | 19.60 |
| 07/30/90 | | A1-A6 | 14.82 | 0.57 | 1.09 | 1.35 | 0.57 | 16.48 |
| 07/30/90 | | A1-A6 | 16.55 | 0.68 | 1.20 | 1.19 | 0.71 | 18.43 |
| 07/30/90 | | A1-A6 | 17.37 | 0.65 | 1.08 | 1.50 | 0.60 | 19.10 |
| 07/30/90 | | A1-A6 | 14.01 | 0.62 | 1.09 | 1.99 | 0.62 | 15.72 |
| 07/30/90 | | A1-A6 | 16.27 | 0.64 | 0.98 | 1.28 | 0.58 | 17.89 |
| 07/30/90 | | A1-A6 | 15.96 | 0.83 | 0.91 | 1.86 | 0.68 | 17.70 |
| 07/30/90 | | A1-A6 | 17.43 | 0.88 | 0.82 | 1.08 | 0.99 | 19.13 |
| 07/30/90 | | A1-A6 | 16.17 | 0.75 | 0.94 | 1.22 | 0.71 | 17.86 |
| 07/30/90 | | A1-A6 | 17.31 | 0.71 | 0.93 | 1.51 | 0.81 | 18.95 |
| 07/30/90 | | A1-A6 | 17.26 | 0.56 | 0.88 | 1.30 | 0.76 | 18.70 |
| 07/30/90 | | A1-A6 | 15.33 | 0.57 | 0.82 | 1.48 | 0.58 | 16.72 |
| 07/30/90 | | A1-A6 | 14.41 | 0.70 | 0.77 | 1.22 | 0.60 | 15.88 |
| 07/30/90 | | A1-A6 | 17.98 | 0.90 | 0.96 | 1.52 | 0.79 | 19.84 |
| 07/30/90 | | A1-A6 | 17.92 | 1.17 | 0.90 | 1.39 | 0.91 | 19.99 |
| 07/30/90 | | A1-A6 | 17.73 | 1.07 | 1.11 | 1.86 | 1.18 | 19.91 |
| 07/30/90 | | A1-A6 | 13.64 | 0.72 | 0.85 | 1.44 | 0.94 | 15.21 |
| 07/30/90 | | A1-A6 | 15.82 | 0.59 | 1.00 | 1.16 | 0.65 | 17.41 |
| 07/30/90 | | A1-A6 | 12.49 | 0.63 | 0.76 | 0.94 | 0.65 | 13.88 |
| 07/30/90 | | A1-A6 | 12.71 | 0.93 | 0.85 | 0.79 | 0.54 | 14.50 |

Background QC Data Set #1

| DATE EVALUATED | SAMPLE LOCATION | DETECTOR | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-------------------|--------------------|----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| 07/30/90 | | A1-A6 | 17.80 | 1.05 | 1.19 | 1.57 | 0.90 | 20.04 |
| 07/30/90 | | A1-A6 | 16.51 | 0.57 | 1.02 | 0.63 | 1.10 | 18.10 |
| 07/30/90 | | A1-A6 | 15.00 | 1.49 | 1.02 | 1.27 | 0.55 | 17.51 |
| 07/30/90 | | A1-A6 | 20.24 | 1.03 | 1.15 | 1.71 | 1.33 | 22.42 |
| 07/30/90 | | A1-A6 | 17.68 | 1.14 | 0.94 | 1.91 | 1.03 | 19.76 |
| 07/30/90 | | A1-A6 | 15.57 | 1.17 | 0.88 | 1.39 | 1.19 | 17.62 |
| 07/30/90 | | A1-A6 | 15.74 | 1.17 | 0.73 | 1.29 | 1.26 | 17.64 |
| 08/06/90 | SURFACE | A1-A6 | 14.24 | 0.94 | 1.10 | 1.32 | 1.00 | 16.28 |
| 08/06/90 | SAMPLES | A1-A6 | 17.81 | 1.32 | 1.26 | 2.30 | 1.34 | 20.38 |
| 08/06/90 | | A1-A6 | 16.76 | 1.50 | 1.26 | 2.55 | 1.46 | 19.52 |
| 08/06/90 | [PSDITSUR.WK] | A1-A6 | 19.20 | 1.18 | 1.04 | 2.12 | 1.13 | 21.42 |
| 08/06/90 | | A1-A6 | 23.13 | 1.72 | 1.52 | 3.59 | 1.63 | 26.38 |
| 08/06/90 | | A1-A6 | 14.96 | 0.87 | 0.90 | 1.31 | 1.10 | 16.73 |
| 08/06/90 | | A1-A6 | 18.04 | 1.27 | 1.17 | 2.87 | 1.29 | 20.48 |
| 08/06/90 | | A1-A6 | 14.12 | 0.98 | 1.05 | 1.99 | 1.09 | 16.15 |
| 08/06/90 | | A1-A6 | 16.27 | 1.26 | 1.06 | 1.28 | 1.19 | 18.59 |
| 08/06/90 | | A1-A6 | 18.73 | 1.13 | 1.16 | 1.07 | 1.24 | 21.02 |
| 08/06/90 | | A1-A6 | 19.24 | 1.22 | 1.19 | 1.91 | 1.15 | 21.65 |
| 08/06/90 | | A1-A6 | 18.90 | 1.15 | 1.19 | 1.88 | 1.24 | 21.23 |
| 08/06/90 | | A1-A6 | 17.13 | 1.15 | 0.85 | 2.00 | 1.18 | 19.13 |
| 08/06/90 | | A1-A6 | 12.21 | 1.13 | 0.80 | 1.78 | 1.03 | 14.14 |
| 08/06/90 | | A1-A6 | 18.54 | 1.40 | 1.29 | 2.69 | 1.50 | 21.23 |
| 08/06/90 | | A1-A6 | 18.84 | 1.24 | 0.79 | 1.59 | 1.11 | 20.86 |
| 08/06/90 | | A1-A6 | 18.74 | 1.01 | 1.17 | 1.68 | 1.13 | 20.92 |
| 08/06/90 | | A1-A6 | 14.36 | 0.91 | 1.03 | 1.74 | 1.07 | 16.30 |
| 08/06/90 | | A1-A6 | 14.62 | 1.02 | 1.00 | 2.29 | 0.94 | 16.64 |
| 08/06/90 | | A1-A6 | 15.96 | 1.05 | 0.98 | 1.80 | 1.15 | 17.99 |
| 08/06/90 | | A1-A6 | 14.67 | 1.03 | 1.09 | 1.02 | 1.09 | 16.79 |
| 08/06/90 | | A1-A6 | 17.78 | 1.35 | 1.15 | 2.36 | 1.20 | 20.28 |
| 08/06/90 | | A1-A6 | 17.87 | 1.06 | 0.97 | 1.23 | 0.89 | 19.90 |
| 08/06/90 | | A1-A6 | 16.50 | 0.94 | 0.97 | 2.15 | 1.07 | 18.41 |
| 08/06/90 | | A1-A6 | 13.48 | 1.12 | 0.92 | 1.76 | 0.98 | 15.53 |
| 08/06/90 | | A1-A6 | 10.51 | 0.97 | 0.86 | 1.03 | 0.96 | 12.35 |
| 08/06/90 | | A1-A6 | 15.44 | 1.10 | 0.92 | 2.26 | 0.87 | 17.46 |
| 08/06/90 | | A1-A6 | 15.27 | 0.87 | 0.86 | 1.11 | 0.90 | 17.00 |
| 08/06/90 | | A1-A6 | 14.89 | 0.84 | 0.88 | 1.22 | 0.95 | 16.61 |
| 08/06/90 | | A1-A6 | 15.63 | 0.94 | 0.97 | 1.47 | 0.87 | 17.54 |
| 08/06/90 | | A1-A6 | 17.92 | 1.03 | 0.95 | 1.89 | 1.05 | 19.90 |
| Nov-89 | TSF-SUB | 621 | 13.50 | 0.99 | 0.82 | 1.98 | 1.01 | 15.31 |
| Nov-89 | TSF-SUR | 621 | 13.70 | 1.12 | 1.02 | 2.18 | 1.16 | 15.84 |
| Nov-89 | TSF-SUB | 768 | 13.70 | 0.89 | 0.91 | 1.55 | 0.97 | 15.50 |
| Nov-89 | TSF-SUR | 568 | 13.80 | 1.06 | 1.06 | 2.98 | 1.12 | 15.92 |
| Nov-89 | TSF-SUB | 625 | 13.80 | 1.11 | 0.88 | 2.29 | 1.01 | 15.79 |
| Nov-89 | TSF-SUR | 672 | 13.80 | 1.14 | 1.15 | 2.17 | 1.05 | 16.09 |
| Nov-89 | TSF-SUR | 798 | 13.90 | 1.05 | 0.94 | 2.17 | 1.00 | 15.89 |
| Nov-89 | TSF | 603 | 14.00 | 1.05 | 1.02 | 3.44 | 1.01 | 16.07 |
| Nov-89 | TSF | 721 | 14.30 | 1.05 | 0.91 | 2.10 | 1.05 | 16.26 |
| Nov-89 | TSF-SUB | 596 | 14.40 | 1.12 | 1.10 | 2.00 | 1.09 | 16.62 |

Background QC Data Set #1

| DATE EVALUATED | SAMPLE LOCATION | DETECTOR | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-------------------|--------------------|----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| Nov-89 | TSF-SUB | 662 | 14.40 | 0.99 | 0.78 | 1.78 | 0.99 | 16.16 |
| Nov-89 | TSF-SUR | 534 | 14.40 | 1.09 | 0.97 | 2.79 | 1.08 | 16.46 |
| Feb-90 | ARA-SUR | 525 | 14.50 | 1.03 | 0.81 | 1.68 | 1.02 | 16.34 |
| Feb-90 | ARA | 627 | 14.50 | 0.97 | 0.87 | 1.30 | 0.83 | 16.33 |
| Nov-89 | TSF-SUR | 628 | 14.50 | 1.07 | 1.02 | 2.15 | 1.05 | 16.59 |
| Nov-89 | TSF-SUB | 700 | 14.60 | 1.02 | 0.87 | 2.09 | 1.04 | 16.49 |
| Dec-89 | CFA-SUB | 606 | 14.60 | 1.04 | 0.88 | 0.93 | 1.19 | 16.52 |
| Nov-89 | TSF-SUB | 656 | 14.60 | 1.16 | 1.00 | 1.81 | 1.12 | 16.76 |
| Nov-89 | TSF-SUB | 650 | 14.70 | 1.18 | 0.99 | 1.83 | 1.10 | 16.87 |
| Nov-89 | TSF | 702 | 14.90 | 1.18 | 1.00 | 2.35 | 1.11 | 17.08 |
| Nov-89 | TSF-SUB | 548 | 14.90 | 1.04 | 1.13 | 2.12 | 1.05 | 17.07 |
| Nov-89 | TSF-SS | 473 | 15.00 | 1.14 | 1.05 | 1.60 | 1.01 | 17.19 |
| Nov-89 | TSF-SUR | 590 | 15.00 | 1.14 | 1.10 | 2.20 | 1.09 | 17.24 |
| Nov-87 | TSF-SUR | 553 | 15.00 | 1.09 | 1.08 | 2.36 | 1.10 | 17.17 |
| Feb-90 | ARA-SUB | 447 | 15.10 | 1.05 | 0.78 | 2.21 | 1.03 | 16.93 |
| Nov-89 | TSF-SUB | 570 | 15.10 | 1.25 | 1.06 | 1.27 | 1.16 | 17.41 |
| Nov-89 | TSF-SUB | 581 | 15.10 | 1.15 | 1.03 | 2.31 | 1.11 | 17.28 |
| Nov-89 | TSF-SUR | 529 | 15.30 | 1.20 | 1.18 | 2.61 | 1.23 | 17.68 |
| Nov-89 | TSF-SUR | 523 | 15.40 | 1.15 | 1.19 | 1.96 | 0.93 | 17.74 |
| Nov-89 | TSF | 579 | 15.40 | 1.07 | 1.20 | 2.16 | 1.09 | 17.67 |
| Nov-89 | TSF-SUR | 609 | 15.40 | 1.19 | 1.34 | 2.51 | 1.14 | 17.93 |
| Dec-89 | CFA-SUB | 552 | 15.40 | 1.11 | 0.96 | 2.23 | 1.08 | 17.47 |
| Nov-89 | TSF-SUR | 588 | 15.70 | 1.08 | 1.25 | 2.27 | 1.11 | 18.03 |
| Dec-89 | CFA-SUB | 424 | 15.70 | 1.20 | 1.38 | 2.95 | 1.23 | 18.28 |
| Dec-89 | CFA-SUB | 540 | 15.70 | 1.25 | 0.95 | 1.13 | 1.22 | 17.90 |
| Dec-89 | CFA-SUB | 524 | 15.80 | 1.27 | 1.17 | 3.06 | 1.23 | 18.24 |
| Nov-89 | TSF-SUR | 518 | 15.80 | 1.18 | 1.07 | 4.54 | 1.15 | 18.05 |
| Nov-89 | TSF-SUR | 798 | 15.80 | 1.00 | 0.94 | 2.04 | 0.91 | 17.74 |
| Nov-89 | TSF-SUR | 661 | 16.00 | 1.09 | 1.11 | 2.32 | 1.18 | 18.20 |
| Nov-89 | TSF-SUR | 567 | 16.10 | 1.21 | 0.98 | 2.59 | 1.13 | 18.29 |
| Dec-89 | CFA-SUR | 578 | 16.20 | 1.22 | 1.36 | 1.38 | 1.12 | 18.78 |
| Nov-89 | TSF-SUB | 551 | 16.20 | 1.29 | 1.02 | 2.24 | 1.10 | 18.51 |
| Nov-89 | TSF-SUR | 592 | 16.30 | 1.19 | 1.12 | 2.00 | 1.09 | 18.61 |
| Feb-90 | ARA-SUB | 611 | 16.30 | 1.09 | 0.68 | 1.78 | 1.10 | 18.07 |
| Nov-89 | TSF-SUR | 545 | 16.30 | 1.25 | 0.96 | 2.62 | 1.17 | 18.51 |
| Nov-89 | TSF-SUR | 537 | 16.30 | 1.34 | 1.23 | 2.47 | 1.24 | 18.87 |
| Nov-89 | TSF-SUR | 532 | 16.40 | 1.17 | 1.18 | 2.98 | 1.26 | 18.75 |
| Nov-89 | TSF-SUB | 528 | 16.40 | 1.26 | 1.06 | 2.60 | 1.16 | 18.72 |
| Nov-89 | TSF-SUR | 528 | 16.40 | 1.16 | 1.24 | 2.67 | 1.23 | 18.80 |
| Nov-89 | TSF-SUR | 713 | 16.40 | 1.05 | 0.99 | 2.53 | 1.19 | 18.44 |
| Nov-89 | TSF-SUB | 566 | 16.50 | 1.30 | 1.06 | 2.17 | 1.23 | 18.86 |
| Nov-89 | TSE-SUR | 545 | 16.50 | 1.32 | 1.13 | 2.42 | 1.24 | 18.95 |
| Nov-89 | TSF-SUB | 481 | 16.60 | 1.15 | 1.08 | 2.57 | 1.24 | 18.83 |
| Nov-89 | TSF-SUR | 592 | 16.60 | 1.26 | 0.97 | 2.20 | 1.27 | 18.83 |
| Nov-89 | TSF | 541 | 16.80 | 1.19 | 1.10 | 2.55 | 1.22 | 19.09 |
| Dec-89 | CFA-SUR | 538 | 16.80 | 1.20 | 1.35 | 3.08 | 1.35 | 19.35 |
| Dec-89 | CFA-SUB | 527 | 16.90 | 1.50 | 0.95 | 2.15 | 1.40 | 19.35 |
| Nov-89 | TSF-SUR | 562 | 16.90 | 1.17 | 1.03 | 2.48 | 1.18 | 19.10 |

Background QC Data Set #1

| DATE EVALUATED | SAMPLE LOCATION | DETECTOR | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-------------------|--------------------|----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| Nov-89 | TSF-SUR | 629 | 16.90 | 1.21 | 1.08 | 2.78 | 1.21 | 19.19 |
| Dec-89 | CFA-SUR | 516 | 16.90 | 1.21 | 1.13 | 2.61 | 1.26 | 19.24 |
| Nov-89 | TSF-SUR | 213 | 17.00 | 1.55 | 1.44 | 3.36 | 1.45 | 19.99 |
| Dec-89 | CFA-SUR | 515 | 17.00 | 1.33 | 1.24 | 2.19 | 1.17 | 19.57 |
| Dec-89 | CFA-SUR | 533 | 17.20 | 1.21 | 1.36 | 2.22 | 1.18 | 19.77 |
| Dec-89 | CFA-SUR | 598 | 17.30 | 1.26 | 1.20 | 2.22 | 1.32 | 19.76 |
| Nov-89 | TSF | 544 | 17.30 | 1.26 | 1.23 | 2.40 | 1.24 | 19.79 |
| Nov-89 | TSF-SUR | 505 | 17.40 | 1.31 | 1.16 | 3.48 | 1.29 | 19.87 |
| Nov-89 | TSF-SUR | 563 | 17.50 | 1.30 | 1.33 | 2.62 | 1.28 | 20.13 |
| Dec-89 | CFA-SUR | 424 | 17.50 | 1.29 | 1.28 | 2.67 | 1.24 | 20.07 |
| Nov-89 | TSF-SUR | 606 | 17.60 | 1.24 | 1.12 | 2.62 | 1.03 | 19.96 |
| Nov-89 | TSF-SUR | 552 | 17.60 | 1.27 | 1.16 | 2.43 | 1.24 | 20.03 |
| Nov-89 | TSF-SUR | 586 | 17.60 | 1.27 | 1.25 | 2.29 | 1.26 | 20.12 |
| Dec-89 | CFA-SUR | 528 | 17.80 | 1.31 | 1.39 | 2.64 | 1.34 | 20.50 |
| Dec-89 | CFA-SUR | 662 | 17.80 | 1.30 | 1.09 | 2.13 | 1.26 | 20.19 |
| Dec-89 | CFA-SUR | 615 | 17.90 | 1.18 | 1.20 | 2.73 | 1.36 | 20.28 |
| Dec-89 | CFA-SUR | 652 | 18.00 | 1.28 | 1.16 | 2.35 | 1.16 | 20.44 |
| Feb-90 | ARA | 461 | 18.00 | 1.42 | 0.95 | 1.88 | 1.34 | 20.37 |
| Nov-89 | TSF-SUR | 560 | 18.10 | 1.32 | 1.55 | 2.79 | 1.28 | 20.97 |
| Dec-89 | CFA-SUB | 511 | 18.30 | 1.44 | 1.10 | 1.13 | 1.31 | 20.84 |
| Dec-89 | CFA-SUR | 654 | 18.40 | 1.29 | 1.31 | 1.66 | 1.28 | 21.00 |
| Nov-89 | TSF-SUR | 454 | 18.40 | 1.36 | 1.28 | 0.67 | 1.37 | 21.04 |
| Dec-89 | CFA-SUR | 495 | 18.40 | 1.18 | 1.19 | 2.47 | 1.22 | 20.77 |
| Dec-89 | CFA-SUR | 499 | 18.60 | 1.30 | 1.16 | 2.24 | 1.30 | 21.06 |
| Dec-89 | CFA-SUR | 561 | 18.60 | 1.30 | 1.30 | 1.50 | 1.32 | 21.20 |
| Nov-89 | TSF-SUR | 546 | 18.60 | 1.38 | 1.38 | 2.61 | 1.39 | 21.36 |
| Dec-89 | CFA-SUR | 496 | 18.70 | 1.35 | 1.17 | 2.16 | 1.36 | 21.22 |
| Dec-89 | CFA-SUR | 557 | 18.70 | 1.32 | 1.25 | 2.32 | 1.26 | 21.27 |
| Dec-89 | CFA-SUR | 552 | 19.00 | 1.37 | 1.32 | 2.41 | 1.31 | 21.69 |
| Dec-89 | CFA-SUR | 398 | 19.30 | 1.42 | 1.30 | 3.33 | 1.40 | 22.02 |
| Dec-89 | CFA-SUR | 503 | 19.40 | 1.26 | 1.12 | 2.59 | 1.33 | 21.78 |
| Feb-90 | ARA-SUB | 412 | 19.40 | 1.39 | 0.77 | 2.13 | 1.33 | 21.56 |
| Dec-89 | CFA-SUR | 556 | 19.70 | 1.30 | 1.17 | 1.34 | 1.36 | 22.17 |
| Nov-89 | TSF-SUR | 256 | 21.10 | 1.57 | 1.44 | 3.56 | 1.65 | 24.11 |

Background QC Data Set #1

BACKGROUND QUALITY CONTROL STUDY, DATA SET #1 STATISTICAL SUMMARY

ALL DATA

| | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| COUNT: | 221 | 221 | 221 | 221 | 221 | 221 |
| AVERAGE: | 16.53 | 1.14 | 1.13 | 2.02 | 1.12 | 18.80 |
| STD.DEV: | 2.13 | 0.27 | 0.20 | 0.64 | 0.26 | 2.43 |
| VARIANCE: | 4.55 | 0.07 | 0.04 | 0.41 | 0.07 | 5.92 |
| MINIMUM: | 9.58 | 0.45 | 0.68 | 0.48 | 0.35 | 10.92 |
| MAXIMUM: | 23.13 | 1.72 | 1.65 | 4.54 | 1.65 | 26.38 |

ALL DATA WITH CHEM POND AND 4 OUTLIERS REMOVED

| | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| COUNT: | 217 | 184 | 184 | 184 | 184 | 217 |
| AVERAGE: | 16.64 | 1.23 | 1.16 | 2.14 | 1.21 | 18.67 |
| STD.DEV: | 1.97 | 0.17 | 0.20 | 0.60 | 0.17 | 2.46 |
| VARIANCE: | 3.89 | 0.03 | 0.04 | 0.36 | 0.03 | 6.03 |
| MINIMUM: | 11.59 | 0.53 | 0.68 | 0.67 | 0.55 | 11.59 |
| MAXIMUM: | 23.13 | 1.72 | 1.65 | 4.54 | 1.65 | 26.38 |

ALL DATA WITH ONLY THE 4 OUTLIERS REMOVED

| | K-40 (pCi/g) | Pb-212 (pCi/g) | Pb-214 (pCi/g) | Ra-226 (pCi/g) | Ac-228 (pCi/g) | TOTAL (pCi/g) |
|-----------|-----------------|-------------------|-------------------|-------------------|-------------------|------------------|
| COUNT: | 217 | 217 | 217 | 217 | 217 | 217 |
| AVERAGE: | 16.64 | 1.15 | 1.13 | 2.04 | 1.13 | 18.93 |
| STD.DEV: | 1.97 | 0.26 | 0.20 | 0.63 | 0.25 | 2.26 |
| VARIANCE: | 3.89 | 0.07 | 0.04 | 0.40 | 0.06 | 5.09 |
| MINIMUM: | 11.59 | 0.48 | 0.68 | 0.48 | 0.35 | 12.81 |
| MAXIMUM: | 23.13 | 1.72 | 1.65 | 4.54 | 1.65 | 26.38 |

Background QC Data Set #2

BACKGROUND QUALITY CONTROL STUDY, DATA SET #2

ENVIRONMENTAL SOIL SAMPLES

| DATE COLLECTED | SAMPLE DESCRIPTION | DETECTOR | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO | COMMENTS |
|-------------------|-----------------------|----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------|
| Nov-89 | TSF | A1-A6 | 0.82 | | | | 1.98 | | 2.41 | |
| Nov-89 | TSF | A1-A6 | 1.02 | | | | 2.18 | | 2.14 | |
| Nov-89 | TSF | A1-A6 | 0.91 | | | | 1.55 | | 1.71 | |
| Nov-89 | SURFACE | A1-A6 | 1.06 | | | | 2.98 | | 2.81 | |
| Nov-89 | SAMPLES | A1-A6 | 0.88 | | | | 2.29 | | 2.60 | |
| Nov-89 | TSF | A1-A6 | 1.15 | | | | 2.17 | | 1.89 | |
| Nov-89 | TSF | A1-A6 | 0.94 | | | | 2.17 | | 2.31 | |
| Nov-89 | TSF | A1-A6 | 1.02 | | | | 3.44 | | 3.37 | |
| Nov-89 | TSF | A1-A6 | 0.91 | | | | 2.10 | | 2.31 | |
| Nov-89 | TSF | A1-A6 | 1.10 | | | | 2.00 | | 1.82 | |
| Nov-89 | TSF | A1-A6 | 0.78 | | | | 1.78 | | 2.29 | |
| Nov-89 | TSF | A1-A6 | 0.97 | | | | 2.79 | | 2.89 | |
| Nov-89 | TSF | A1-A6 | 1.02 | | | | 2.15 | | 2.11 | |
| Nov-89 | TSF | A1-A6 | 0.87 | | | | 2.09 | | 2.40 | |
| Nov-89 | TSF | A1-A6 | 1.00 | | | | 1.81 | | 1.81 | |
| Nov-89 | TSF | A1-A6 | 0.99 | | | | 1.83 | | 1.84 | |
| Nov-89 | TSF | A1-A6 | 1.00 | | | | 2.35 | | 2.36 | |
| Nov-89 | TSF | A1-A6 | 1.13 | | | | 2.12 | | 1.88 | |
| Nov-89 | TSF | A1-A6 | 1.05 | | | | 1.60 | | 1.52 | |
| Nov-89 | TSF | A1-A6 | 1.10 | | | | 2.20 | | 2.00 | |
| Nov-89 | TSF | A1-A6 | 1.08 | | | | 2.36 | | 2.19 | |
| Nov-89 | TSF | A1-A6 | 1.06 | | | | 1.27 | | 1.20 | |
| Nov-89 | TSF | A1-A6 | 1.03 | | | | 2.31 | | 2.24 | |
| Nov-89 | TSF | A1-A6 | 1.18 | | | | 2.61 | | 2.21 | |
| Nov-89 | TSF | A1-A6 | 1.19 | | | | 1.96 | | 1.65 | |
| Nov-89 | TSF | A1-A6 | 1.20 | | | | 2.16 | | 1.80 | |
| Nov-89 | TSF | A1-A6 | 1.34 | | | | 2.51 | | 1.87 | |
| Nov-89 | TSF | A1-A6 | 1.25 | | | | 2.27 | | 1.82 | |
| Nov-89 | TSF | A1-A6 | 0.94 | | | | 2.04 | | 2.17 | |
| Nov-89 | TSF | A1-A6 | 1.11 | | | | 2.32 | | 2.09 | |
| Nov-89 | TSF | A1-A6 | 0.98 | | | | 2.59 | | 2.64 | |
| Nov-89 | TSF | A1-A6 | 1.02 | | | | 2.24 | | 2.20 | |
| Nov-89 | TSF | A1-A6 | 1.12 | | | | 2.00 | | 1.79 | |
| Nov-89 | TSF | A1-A6 | 0.96 | | | | 2.62 | | 2.72 | |
| Nov-89 | TSF | A1-A6 | 1.23 | | | | 2.47 | | 2.01 | |
| Nov-89 | TSF | A1-A6 | 1.18 | | | | 2.98 | | 2.53 | |
| Nov-89 | TSF | A1-A6 | 1.06 | | | | 2.60 | | 2.45 | |
| Nov-89 | TSF | A1-A6 | 1.24 | | | | 2.67 | | 2.15 | |
| Nov-89 | TSF | A1-A6 | 0.99 | | | | 2.53 | | 2.56 | |
| Nov-89 | TSF | A1-A6 | 1.06 | | | | 2.17 | | 2.05 | |
| Nov-89 | TSF | A1-A6 | 1.13 | | | | 2.42 | | 2.14 | |
| Nov-89 | TSF | A1-A6 | 1.08 | | | | 2.57 | | 2.38 | |
| Nov-89 | TSF | A1-A6 | 0.97 | | | | 2.20 | | 2.28 | |
| Nov-89 | TSF | A1-A6 | 1.10 | | | | 2.55 | | 2.32 | |
| Nov-89 | TSF | A1-A6 | 1.03 | | | | 2.48 | | 2.41 | |
| Nov-89 | TSF | A1-A6 | 1.08 | | | | 2.78 | | 2.57 | |
| Nov-89 | TSF | A1-A6 | 1.44 | | | | 3.36 | | 2.33 | |
| Nov-89 | TSF | A1-A6 | 1.23 | | | | 2.40 | | 1.95 | |
| Nov-89 | TSF | A1-A6 | 1.16 | | | | 3.48 | | 3.00 | |
| Nov-89 | TSF | A1-A6 | 1.33 | | | | 2.62 | | 1.97 | |
| Nov-89 | TSF | A1-A6 | 1.12 | | | | 2.62 | | 2.34 | |
| Nov-89 | TSF | A1-A6 | 1.16 | | | | 2.43 | | 2.09 | |
| Nov-89 | TSF | A1-A6 | 1.25 | | | | 2.29 | | 1.83 | |
| Nov-89 | TSF | A1-A6 | 1.55 | | | | 2.79 | | 1.80 | |
| Nov-89 | TSF | A1-A6 | 1.38 | | | | 2.61 | | 1.89 | |
| Nov-89 | TSF | A1-A6 | 1.44 | | | | 3.56 | | 2.47 | |
| Dec-89 | CFA | A1-A6 | 0.88 | | | | 0.93 | | 1.06 | |
| Dec-89 | CFA | A1-A6 | 0.96 | | | | 2.23 | | 2.32 | |
| Dec-89 | CFA | A1-A6 | 1.38 | | | | 2.95 | | 2.14 | |

Background QC Data Set #2

| DATE COLLECTED | SAMPLE DESCRIPTION | DETECTOR | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO | COMMENTS |
|-------------------|-----------------------|----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|--------------------|
| Dec-89 | CFA | A1-A6 | 0.95 | | | | 1.13 | | 1.19 | |
| Dec-89 | CFA | A1-A6 | 1.17 | | | | 3.06 | | 2.62 | |
| Dec-89 | CFA | A1-A6 | 1.36 | | | | 1.38 | | 1.01 | |
| Dec-89 | CFA | A1-A6 | 1.35 | | | | 3.08 | | 2.28 | |
| Dec-89 | CFA | A1-A6 | 0.95 | | | | 2.15 | | 2.25 | |
| Dec-89 | CFA | A1-A6 | 1.13 | | | | 2.61 | | 2.31 | |
| Dec-89 | CFA | A1-A6 | 1.24 | | | | 2.19 | | 1.77 | |
| Dec-89 | CFA | A1-A6 | 1.36 | | | | 2.22 | | 1.63 | |
| Dec-89 | CFA | A1-A6 | 1.20 | | | | 2.22 | | 1.85 | |
| Dec-89 | CFA | A1-A6 | 1.28 | | | | 2.67 | | 2.09 | |
| Dec-89 | CFA | A1-A6 | 1.09 | | | | 2.13 | | 1.95 | |
| Dec-89 | CFA | A1-A6 | 1.20 | | | | 2.73 | | 2.28 | |
| Dec-89 | CFA | A1-A6 | 1.16 | | | | 2.35 | | 2.03 | |
| Dec-89 | CFA | A1-A6 | 1.39 | | | | 2.64 | | 1.90 | |
| Dec-89 | CFA | A1-A6 | 1.10 | | | | 1.13 | | 1.03 | |
| Dec-89 | CFA | A1-A6 | 1.31 | | | | 1.66 | | 1.27 | |
| Dec-89 | CFA | A1-A6 | 1.19 | | | | 2.47 | | 2.08 | |
| Dec-89 | CFA | A1-A6 | 1.16 | | | | 2.24 | | 1.93 | |
| Dec-89 | CFA | A1-A6 | 1.30 | | | | 1.50 | | 1.15 | |
| Dec-89 | CFA | A1-A6 | 1.17 | | | | 2.16 | | 1.85 | |
| Dec-89 | CFA | A1-A6 | 1.25 | | | | 2.32 | | 1.86 | |
| Dec-89 | CFA | A1-A6 | 1.32 | | | | 2.41 | | 1.83 | |
| Dec-89 | CFA | A1-A6 | 1.30 | | | | 3.33 | | 2.56 | |
| Dec-89 | CFA | A1-A6 | 1.12 | | | | 2.59 | | 2.31 | |
| Dec-89 | CFA | A1-A6 | 1.17 | | | | 1.34 | | 1.15 | |
| Feb-90 | ARA | A1-A6 | 0.77 | | | | 2.13 | | 2.78 | |
| Feb-90 | ARA | A1-A6 | 0.95 | | | | 1.88 | | 1.98 | |
| Feb-90 | ARA | A1-A6 | 0.81 | | | | 1.68 | | 2.07 | |
| Feb-90 | ARA | A1-A6 | 0.87 | | | | 1.30 | | 1.50 | |
| Feb-90 | ARA | A1-A6 | 0.78 | | | | 2.21 | | 2.84 | |
| Feb-90 | ARA | A1-A6 | 0.68 | | | | 1.78 | | 2.64 | |
| 07/30/90 | CHEM POND | A1-A6 | 1.12 | | | | 1.87 | | 1.67 | MOST CHEM POND |
| 07/30/90 | | A1-A6 | 1.46 | | | | 1.62 | | 1.11 | THORIUM DAUGHTER |
| 07/30/90 | SURFACE | A1-A6 | 0.79 | | | | 1.53 | | 1.94 | RESULTS WERE VERY |
| 07/30/90 | SAMPLES | A1-A6 | 1.33 | | | | 2.78 | | 2.09 | ATYPICAL AND |
| 07/30/90 | | A1-A6 | 1.08 | | | | 1.45 | | 1.35 | THEREFORE EXCLUDED |
| 07/30/90 | | A1-A6 | 0.74 | | | | 1.66 | | 2.24 | |
| 07/30/90 | | A1-A6 | 0.93 | | | | 1.52 | | 1.63 | |
| 07/30/90 | | A1-A6 | 0.74 | | | | 1.54 | | 2.09 | |
| 07/30/90 | | A1-A6 | 1.22 | | | | 2.61 | | 2.15 | |
| 07/30/90 | | A1-A6 | 1.25 | | | | 2.39 | | 1.91 | |
| 07/30/90 | | A1-A6 | 1.04 | | | | 1.71 | | 1.64 | |
| 07/30/90 | | A1-A6 | 1.09 | | | | 1.35 | | 1.24 | |
| 07/30/90 | | A1-A6 | 1.20 | | | | 1.19 | | 0.99 | |
| 07/30/90 | | A1-A6 | 1.08 | | | | 1.50 | | 1.39 | |
| 07/30/90 | | A1-A6 | 1.09 | | | | 1.99 | | 1.82 | |
| 07/30/90 | | A1-A6 | 0.98 | | | | 1.28 | | 1.30 | |
| 07/30/90 | | A1-A6 | 0.91 | | | | 1.86 | | 2.05 | |
| 07/30/90 | | A1-A6 | 0.82 | | | | 1.08 | | 1.31 | |
| 07/30/90 | | A1-A6 | 0.94 | | | | 1.22 | | 1.30 | |
| 07/30/90 | | A1-A6 | 0.93 | | | | 1.51 | | 1.62 | |
| 07/30/90 | | A1-A6 | 0.88 | | | | 1.30 | | 1.48 | |
| 07/30/90 | | A1-A6 | 0.82 | | | | 1.48 | | 1.80 | |
| 07/30/90 | | A1-A6 | 0.77 | | | | 1.22 | | 1.58 | |
| 07/30/90 | | A1-A6 | 0.96 | | | | 1.52 | | 1.58 | |
| 07/30/90 | | A1-A6 | 0.90 | | | | 1.39 | | 1.55 | |
| 07/30/90 | | A1-A6 | 1.11 | | | | 1.86 | | 1.67 | |
| 07/30/90 | | A1-A6 | 0.85 | | | | 1.44 | | 1.69 | |
| 07/30/90 | | A1-A6 | 1.00 | | | | 1.16 | | 1.17 | |
| 07/30/90 | | A1-A6 | 0.76 | | | | 0.94 | | 1.24 | |
| 07/30/90 | | A1-A6 | 0.85 | | | | 0.79 | | 0.93 | |
| 07/30/90 | | A1-A6 | 1.19 | | | | 1.57 | | 1.32 | |
| 07/30/90 | | A1-A6 | 1.02 | | | | 1.27 | | 1.25 | |

Background QC Data Set #2

| DATE COLLECTED | SAMPLE DESCRIPTION | DETECTOR | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO | COMMENTS |
|-------------------|-----------------------|----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------|
| 07/30/90 | | A1-A6 | 1.15 | | | | 1.71 | | 1.49 | |
| 07/30/90 | | A1-A6 | 0.94 | | | | 1.91 | | 2.03 | |
| 07/30/90 | | A1-A6 | 0.88 | | | | 1.39 | | 1.57 | |
| 07/30/90 | | A1-A6 | 0.73 | | | | 1.29 | | 1.78 | |
| 08/06/90 | PAINT SHOP | A1-A6 | 1.10 | | | | 1.32 | | 1.20 | |
| 08/06/90 | DITCH | A1-A6 | 1.26 | | | | 2.30 | | 1.84 | |
| 08/06/90 | | A1-A6 | 1.26 | | | | 2.55 | | 2.03 | |
| 08/06/90 | SURFACE | A1-A6 | 1.04 | | | | 2.12 | | 2.03 | |
| 08/06/90 | SAMPLES | A1-A6 | 1.52 | | | | 3.59 | | 2.35 | |
| 08/06/90 | | A1-A6 | 0.90 | | | | 1.31 | | 1.45 | |
| 08/06/90 | | A1-A6 | 1.17 | | | | 2.87 | | 2.45 | |
| 08/06/90 | | A1-A6 | 1.05 | | | | 1.99 | | 1.89 | |
| 08/06/90 | | A1-A6 | 1.06 | | | | 1.28 | | 1.20 | |
| 08/06/90 | | A1-A6 | 1.16 | | | | 1.07 | | 0.92 | |
| 08/06/90 | | A1-A6 | 1.19 | | | | 1.91 | | 1.60 | |
| 08/06/90 | | A1-A6 | 1.19 | | | | 1.88 | | 1.58 | |
| 08/06/90 | | A1-A6 | 0.85 | | | | 2.00 | | 2.36 | |
| 08/06/90 | | A1-A6 | 0.80 | | | | 1.78 | | 2.24 | |
| 08/06/90 | | A1-A6 | 1.29 | | | | 2.69 | | 2.09 | |
| 08/06/90 | | A1-A6 | 0.79 | | | | 1.59 | | 2.02 | |
| 08/06/90 | | A1-A6 | 1.17 | | | | 1.68 | | 1.44 | |
| 08/06/90 | | A1-A6 | 1.03 | | | | 1.74 | | 1.69 | |
| 08/06/90 | | A1-A6 | 1.00 | | | | 2.29 | | 2.29 | |
| 08/06/90 | | A1-A6 | 0.98 | | | | 1.80 | | 1.84 | |
| 08/06/90 | | A1-A6 | 1.09 | | | | 1.02 | | 0.94 | |
| 08/06/90 | | A1-A6 | 1.15 | | | | 2.36 | | 2.05 | |
| 08/06/90 | | A1-A6 | 0.97 | | | | 1.23 | | 1.27 | |
| 08/06/90 | | A1-A6 | 0.97 | | | | 2.15 | | 2.23 | |
| 08/06/90 | | A1-A6 | 0.92 | | | | 1.76 | | 1.91 | |
| 08/06/90 | | A1-A6 | 0.92 | | | | 2.26 | | 2.46 | |
| 08/06/90 | | A1-A6 | 0.86 | | | | 1.11 | | 1.30 | |
| 08/06/90 | | A1-A6 | 0.88 | | | | 1.22 | | 1.39 | |
| 08/06/90 | | A1-A6 | 0.97 | | | | 1.47 | | 1.52 | |
| 08/06/90 | | A1-A6 | 0.95 | | | | 1.89 | | 2.00 | |
| Sep-91 | NPR | A5 | 1.61 | 0.07 | 1.30 | 0.08 | 2.73 | 0.63 | 1.88 | |
| Sep-91 | BASELINE | D2 | 1.20 | 0.05 | 1.27 | 0.06 | 1.99 | 0.36 | 1.61 | |
| Sep-91 | SOIL | D3 | 1.29 | 0.09 | 1.22 | 0.07 | 3.14 | 0.39 | 2.50 | |
| Sep-91 | | A6 | 1.34 | 0.06 | 1.26 | 0.07 | 2.35 | 0.37 | 1.81 | |
| Sep-91 | SAMPLES | A6 | 1.37 | 0.07 | 1.43 | 0.08 | 3.06 | 0.42 | 2.19 | |
| Sep-91 | SEALED | D1 | 1.47 | 0.06 | 1.24 | 0.08 | 2.12 | 0.62 | 1.56 | |
| Sep-91 | 1-mo. | D3 | 1.26 | 0.06 | 1.33 | 0.06 | 3.35 | 0.38 | 2.59 | |
| Sep-91 | | D3 | 1.37 | 0.05 | 1.33 | 0.06 | 2.94 | 0.42 | 2.18 | |
| Sep-91 | | D2 | 1.32 | 0.06 | 1.32 | 0.07 | 3.20 | 0.51 | 2.43 | |
| Sep-91 | | A5 | 1.16 | 0.06 | 1.18 | 0.08 | 1.30 | 0.51 | 1.11 | |
| Sep-91 | | D1 | 1.21 | 0.06 | 1.20 | 0.08 | 2.58 | 0.49 | 2.14 | |
| Sep-91 | | D2 | 1.24 | 0.06 | 1.10 | 0.05 | 2.00 | 0.50 | 1.72 | |
| Sep-91 | | D1 | 1.39 | 0.08 | 1.29 | 0.07 | 2.12 | 0.47 | 1.58 | |
| Sep-91 | | D3 | 1.34 | 0.06 | 1.17 | 0.07 | 1.29 | 0.48 | 1.03 | |
| Sep-91 | | A5 | 1.35 | 0.10 | 1.30 | 0.10 | 2.63 | 0.43 | 1.98 | |
| Sep-91 | | A6 | 1.25 | 0.06 | 1.24 | 0.06 | 1.71 | 0.46 | 1.37 | |
| Sep-91 | | D2 | 1.62 | 0.07 | 1.58 | 0.08 | 3.85 | 0.43 | 2.40 | |
| Sep-91 | | A5 | 1.45 | 0.07 | 1.46 | 0.09 | 2.43 | 0.43 | 1.67 | |
| Sep-91 | | D1 | 1.24 | 0.07 | 1.18 | 0.07 | 1.77 | 0.50 | 1.47 | |
| Sep-91 | | D3 | 1.23 | 0.06 | 1.23 | 0.07 | 2.00 | 0.40 | 1.63 | |
| Sep-91 | | A6 | 1.13 | 0.05 | 1.18 | 0.09 | 1.67 | 0.36 | 1.44 | |
| Sep-91 | | D1 | 1.43 | 0.07 | 1.38 | 0.09 | 2.12 | 0.57 | 1.50 | |
| Sep-91 | | D2 | 1.25 | 0.06 | 1.36 | 0.07 | 1.82 | 0.60 | 1.39 | |
| Sep-91 | | A5 | 1.11 | 0.06 | 1.18 | 0.11 | 2.16 | 0.37 | 1.89 | |
| Sep-91 | | D2 | 1.45 | 0.06 | 1.41 | 0.06 | 2.43 | 0.37 | 1.69 | |
| Sep-91 | | D3 | 1.53 | 0.08 | 1.57 | 0.07 | 2.62 | 0.51 | 1.69 | |
| Sep-91 | | A5 | 1.41 | 0.07 | 1.50 | 0.08 | 2.25 | 0.52 | 1.55 | |
| Sep-91 | | A6 | 1.25 | 0.05 | 1.36 | 0.06 | 2.89 | 0.50 | 2.21 | |
| Sep-91 | | D1 | 1.66 | 0.08 | 1.48 | 0.07 | 3.42 | 0.73 | 2.18 | |
| Sep-91 | | A5 | 1.29 | 0.07 | 1.47 | 0.09 | 3.85 | 0.50 | 2.79 | |
| Sep-91 | | D3 | 1.37 | 0.05 | 1.28 | 0.06 | 2.40 | 0.39 | 1.81 | |
| Sep-91 | | A6 | 1.36 | 0.06 | 1.23 | 0.06 | 3.59 | 0.54 | 2.77 | |

Background QC Data Set #2

| DATE COLLECTED | SAMPLE DESCRIPTION | DETECTOR | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO | COMMENTS |
|-------------------|-----------------------|----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------|
| Sep-91 | | D1 | 1.48 | 0.07 | 1.35 | 0.09 | 3.18 | 0.50 | 2.25 | |
| Sep-91 | | D2 | 1.41 | 0.06 | 1.50 | 0.06 | 2.57 | 0.69 | 1.77 | |
| Sep-91 | | D2 | 1.46 | 0.08 | 1.34 | 0.07 | 2.61 | 0.60 | 1.86 | |
| Sep-91 | | D1 | 1.34 | 0.07 | 1.35 | 0.08 | 3.25 | 0.45 | 2.41 | |
| Sep-91 | | A5 | 1.32 | 0.07 | 1.24 | 0.08 | 2.06 | 0.41 | 1.61 | |
| Sep-91 | | A6 | 1.32 | 0.07 | 1.30 | 0.07 | 2.56 | 0.38 | 1.96 | |
| Sep-91 | | A6 | 1.24 | 0.05 | 1.19 | 0.05 | 2.31 | 0.38 | 1.90 | |
| Sep-91 | | D3 | 1.43 | 0.05 | 1.35 | 0.08 | 3.08 | 0.46 | 2.22 | |
| Sep-91 | | D1 | 1.28 | 0.06 | 1.26 | 0.06 | 3.00 | 0.46 | 2.37 | |
| Sep-91 | | A5 | 1.38 | 0.10 | 1.33 | 0.13 | 2.98 | 0.56 | 2.20 | |
| Sep-91 | | D2 | 1.56 | 0.07 | 1.51 | 0.09 | 1.85 | 0.45 | 1.20 | |
| Sep-91 | | D3 | 1.54 | 0.07 | 1.48 | 0.08 | 2.84 | 0.63 | 1.88 | |
| Sep-91 | | D2 | 1.37 | 0.06 | 1.31 | 0.08 | 2.19 | 0.44 | 1.63 | |
| Mar-92 | PAD A | D3 | 1.00 | 0.05 | 0.77 | 0.05 | 1.92 | 0.38 | 2.17 | |
| Mar-92 | OVERBURDEN | A5 | 0.90 | 0.06 | 0.80 | 0.07 | 1.84 | 0.38 | 2.16 | |
| Mar-92 | | D1 | 0.87 | 0.07 | 0.78 | 0.10 | 1.77 | 0.44 | 2.15 | |
| Mar-92 | SEALED 1-wk. | D1 | 1.12 | 0.06 | 0.97 | 0.07 | 1.98 | 0.50 | 1.90 | |
| Mar-92 | | A6 | 1.11 | 0.05 | 1.02 | 0.09 | 1.47 | 0.34 | 1.38 | |
| Mar-92 | | D3 | 1.11 | 0.05 | 0.98 | 0.07 | 1.70 | 0.32 | 1.63 | |
| Mar-92 | | D2 | 0.97 | 0.06 | 0.99 | 0.06 | 2.00 | 0.31 | 2.04 | |
| Mar-92 | | D1 | 0.99 | 0.06 | 0.93 | 0.09 | 2.16 | 0.47 | 2.25 | |
| Mar-92 | | A5 | 1.04 | 0.06 | 1.02 | 0.08 | 1.80 | 0.46 | 1.75 | |
| Mar-92 | | D2 | 0.93 | 0.07 | 0.88 | 0.06 | 1.56 | 0.35 | 1.72 | |
| Mar-92 | | D3 | 0.89 | 0.05 | 0.82 | 0.05 | 1.84 | 0.40 | 2.16 | |
| Mar-92 | | D1 | 1.20 | 0.08 | 0.92 | 0.07 | 1.56 | 0.43 | 1.47 | |
| Mar-92 | | A6 | 1.06 | 0.06 | 1.11 | 0.07 | 2.50 | 0.35 | 2.31 | |
| Mar-92 | | D2 | 0.97 | 0.06 | 0.99 | 0.06 | 2.00 | 0.31 | 2.04 | |
| Mar-92 | | A6 | 1.06 | 0.07 | 1.11 | 0.07 | 2.50 | 0.35 | 2.31 | |
| Mar-92 | | A6 | 0.98 | 0.06 | 0.96 | 0.06 | 2.36 | 0.38 | 2.43 | |
| Mar-92 | | D2 | 0.94 | 0.05 | 0.86 | 0.05 | 2.79 | 0.42 | 3.10 | |
| Mar-92 | | D3 | 0.97 | 0.06 | 0.83 | 0.07 | 1.60 | 0.42 | 1.77 | |
| Mar-92 | | D1 | 1.07 | 0.06 | 0.97 | 0.09 | 1.47 | 0.53 | 1.44 | |
| Mar-92 | | A6 | 1.05 | 0.06 | 0.92 | 0.06 | 2.18 | 0.55 | 2.22 | |
| Mar-92 | | D3 | 0.91 | 0.05 | 0.80 | 0.06 | 1.85 | 0.46 | 2.15 | |
| Mar-92 | | D2 | 0.98 | 0.06 | 0.90 | 0.08 | 2.39 | 0.42 | 2.54 | |
| Mar-92 | | D3 | 0.91 | 0.05 | 0.85 | 0.08 | 1.39 | 0.69 | 1.57 | |
| May-92 | RWMC | A6 | 1.14 | 0.06 | 1.14 | 0.06 | 3.41 | 0.43 | 2.99 | |
| May-92 | SURFACE | D2 | 1.10 | 0.05 | 0.95 | 0.06 | 2.93 | 0.55 | 2.86 | |
| May-92 | | D3 | 0.84 | 0.05 | 0.81 | 0.05 | 2.01 | 0.37 | 2.44 | |
| May-92 | | D1 | 1.16 | 0.07 | 0.80 | 0.06 | 1.53 | 0.52 | 1.57 | |
| May-92 | | A5 | 0.95 | 0.06 | 1.12 | 0.07 | 1.89 | 0.39 | 1.82 | |
| May-92 | | A5 | 1.09 | 0.07 | 1.04 | 0.08 | 2.16 | 0.63 | 2.03 | |
| May-92 | | D3 | 1.03 | 0.05 | 1.01 | 0.06 | 0.99 | 0.54 | 0.97 | |
| May-92 | | D2 | 0.82 | 0.05 | 0.84 | 0.06 | 1.14 | 0.36 | 1.37 | |
| May-92 | | D1 | 0.99 | 0.06 | 0.92 | 0.07 | 1.80 | 0.44 | 1.88 | |
| May-92 | | D3 | 0.93 | 0.04 | 0.93 | 0.05 | 1.13 | 0.53 | 1.22 | |
| May-92 | | A6 | 1.00 | 0.04 | 0.82 | 0.06 | 2.12 | 0.40 | 2.34 | |
| May-92 | | A5 | 0.94 | 0.06 | 0.92 | 0.05 | 1.87 | 0.31 | 2.01 | |
| May-92 | | D2 | 0.88 | 0.05 | 0.71 | 0.05 | 1.88 | 0.29 | 2.35 | |
| May-92 | | D1 | 0.90 | 0.06 | 0.91 | 0.06 | 2.02 | 0.42 | 2.23 | |
| May-92 | | D3 | 0.97 | 0.05 | 1.00 | 0.06 | 2.28 | 0.37 | 2.32 | |
| May-92 | | A5 | 1.04 | 0.06 | 0.92 | 0.08 | 1.68 | 0.40 | 1.72 | |
| May-92 | | D1 | 1.25 | 0.06 | 1.19 | 0.08 | 3.32 | 0.60 | 2.72 | |
| May-92 | | D2 | 1.19 | 0.05 | 1.24 | 0.06 | 3.24 | 0.43 | 2.66 | |
| May-92 | | A5 | 1.02 | 0.05 | 0.98 | 0.07 | 1.37 | 0.43 | 1.36 | |
| May-92 | | A6 | 1.17 | 0.06 | 1.05 | 0.07 | 2.13 | 0.35 | 1.92 | |
| May-92 | | D2 | 1.04 | 0.06 | 1.06 | 0.07 | 1.57 | 0.29 | 1.49 | |
| May-92 | | D3 | 1.17 | 0.06 | 1.12 | 0.06 | 2.74 | 0.38 | 2.40 | |
| May-92 | | D1 | 1.19 | 0.06 | 1.08 | 0.07 | 1.95 | 0.44 | 1.72 | |
| Jun-92 | RWMC | D1 | 0.77 | 0.05 | 0.62 | 0.06 | 1.14 | 0.41 | 1.65 | |
| Jun-92 | GROUNDWATER | D1 | 0.84 | 0.06 | 0.69 | 0.06 | 2.79 | 0.70 | 3.65 | |
| Jun-92 | PATHWAY | D3 | 0.79 | 0.06 | 0.73 | 0.06 | 1.31 | 0.69 | 1.73 | |
| Jun-92 | SOILS | D2 | 0.94 | 0.07 | 0.82 | 0.05 | 1.72 | 0.57 | 1.95 | |
| Jun-92 | | D2 | 0.71 | 0.05 | 0.55 | 0.05 | 1.64 | 0.34 | 2.59 | |
| Jun-92 | SEALED | D2 | 1.12 | 0.06 | 0.91 | 0.06 | 2.36 | 0.54 | 2.32 | |
| Jun-92 | 1-day | D1 | 0.59 | 0.07 | 0.80 | 0.06 | 1.60 | 0.42 | 2.29 | |

Background QC Data Set #2

| DATE COLLECTED | SAMPLE DESCRIPTION | DETECTOR | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO | COMMENTS |
|-------------------|-----------------------|----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|----------|
| Jun-92 | | D3 | 0.79 | 0.06 | 0.73 | 0.06 | 1.31 | 0.69 | 1.73 | |
| Apr-93 | TSF | A5 | 1.13 | 0.07 | 1.28 | 0.08 | 2.29 | 0.49 | 1.90 | |
| Apr-93 | SEWAGE PLAN | A6 | 1.20 | 0.05 | 1.20 | 0.06 | 1.79 | 0.29 | 1.49 | |
| Apr-93 | SOIL | D1 | 0.99 | 0.07 | 0.96 | 0.07 | | | | |
| Apr-93 | | D2 | 1.01 | 0.06 | 1.02 | 0.06 | 3.58 | 0.68 | 3.52 | |
| Apr-93 | | D1 | 1.08 | 0.07 | 1.00 | 0.08 | 3.85 | 0.62 | 3.70 | |
| Apr-93 | | D3 | 1.03 | 0.06 | 1.09 | 0.06 | 2.00 | 0.42 | 1.89 | |
| Apr-93 | | D4 | 0.95 | 0.04 | 1.05 | 0.05 | 1.03 | 0.47 | 1.02 | |

Background QC Data Set #2

BACKGROUND QUALITY CONTROL STUDY, DATA SET #2 STATISTICAL SUMMARY

ALL DATA

| | Pb-214 (pCi/g) | +/- (pCi/g) | Bi-214 (pCi/g) | +/- (pCi/g) | Ra-226 (pCi/g) | +/- (pCi/g) | Ra/Pb-Bi RATIO |
|-----------|-------------------|----------------|-------------------|----------------|-------------------|----------------|-------------------|
| COUNT: | 262 | 106 | 106 | 106 | 261 | 105 | 261 |
| AVERAGE: | 1.10 | 0.06 | 1.10 | 0.07 | 2.12 | 0.46 | 1.95 |
| STD.DEV: | 0.20 | 0.01 | 0.23 | 0.01 | 0.64 | 0.10 | 0.50 |
| VARIANCE: | 0.04 | 0.00 | 0.05 | 0.00 | 0.41 | 0.01 | 0.25 |
| MINIMUM: | 0.59 | 0.04 | 0.55 | 0.05 | 0.79 | 0.29 | 0.92 |
| MAXIMUM: | 1.66 | 0.10 | 1.58 | 0.13 | 3.85 | 0.73 | 3.70 |

Lockheed Martin Idaho Technologies Company**INTERDEPARTMENTAL COMMUNICATION**

Date: April 13, 1998

To: John Giles MS 3953 6-4158

From: Rosanna Chambers *Rosanna Chambers* MS 3960 6-7729

Subject: COMPARISON OF BI-214 AND PB-214 DATA FROM TAN TSF-07 WITH IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY (INEEL) BACKGROUND DATA - RC-02-98

- References:**
- (a) D. E. Burns letter to T. Green, DEB-23-97, RA-226 Background Concentration Data, December 18, 1997
 - (b) S. M. Medina, Evaluation of Historical and Analytical Data on the TAN TSF-07 Disposal Pond, EGG-ERD-10422, July 1998
 - (c) R. O. Gilbert, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, NY, NY, 1987

A background concentration study of Bi-214 and Pb-214 was performed by L. Don Koeppen of LMITCO (Reference a). The data were compared with data from samples collected from the TAN TSF-07 Disposal Pond (Reference b). The methods used to collect and analyze the samples were similar in the two sampling events. The average concentrations, standard deviations, variances, minima, and maxima for the background study and the TSF-07 pond samples are listed in Table 1.

Table I. Bi-214 and Pb-214 statistics from an INEEL background study and sampling of the TSF-07 disposal pond.

| | Bi-214 | | Pb-214 | |
|-------------------------------|------------------|-------------|------------------|-------------|
| | Background Study | TSF-07 Data | Background Study | TSF-07 Data |
| Number of Samples | 106 | 80 | 262 | 80 |
| Average Concentration (pCi/g) | 1.1 | 0.96 | 1.1 | 1.0 |
| Standard Deviation | 0.23 | 0.18 | 0.20 | 0.19 |
| Variance | 0.05 | 0.03 | 0.04 | 0.04 |
| Minimum Concentration (pCi/g) | 0.55 | 0.59 | 0.59 | 0.58 |
| Maximum Concentration (pCi/g) | 1.58 | 1.45 | 1.66 | 1.55 |

The Wilcoxon Rank Sum Test (Reference c) was used to test the hypotheses that the data from TSF-07 and those from the background study have the same means for both Bi-214 and Pb-214. The results indicate, with 95% probability, that the TSF-07 data belong to the same population as the background study data.

bma

John Giles
April 13, 1998
RC-02-98
Page 2

cc: Caroline Blackmore, MS 3953
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 Doug Kuhns, MS 3920
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